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A different approach to analyzing the Blazhko effect: the VSAA applied to RR Lyr

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Abstract

The mysterious amplitude and phase modulation observed in many RR Lyrae stars has puzzled astronomers for more than a century. Most commonly quoted hypotheses to explain the phenomenon involve nonradial modes, through either resonances or magnetic fields. However, their reality is still being questioned. Maybe an unknown physical mechanism in the star causes the main radial mode to change its properties over time while no nonradial pulsation modes are involved.

Changing Blazhko periods challenge the existing models for the Blazhko effect. Because of its ability to describe a quasi-periodic time series in a simple way, we used the VSAA (Variable Sine Algorithmic Analysis, Tsantilas & Rovithis-Livaniou 2008) in a first and elementary application to monitor the changing Blazhko period of RR Lyr. Assuming modulation of a single pulsation frequency, we applied the VSAA to an extensive data set of RR Lyr, one of the best studied Blazhko stars. The results show how the amplitude and period of the modulation have changed over the past decades.

Individual Objects: RR Lyr

The models for the Blazhko effect and their problems

Over the past few years high-quality time series data of modulated RR Lyrae stars have revealed many facts that still need an explanation. Besides a few to-be-elaborated scenarios such as the one proposed by Stothers (2006), the usually quoted hypotheses require the presence of nonradial modes in the star: the resonance models (e.g., Dziembowski & Mizerski 2004) and the magnetic models (e.g., Shibahashi 2000). Each of the models in their present form favors a different type - more specifically: a different degree ℓ - of nonradial mode. However, stating that the resonance model "comes with" $\ell = 1$ modes and the magnetic model with $\ell = 2$ modes would be far too simplistic. The currently proposed models for the Blazhko effect need to be revisited, and alternative models such as Stothers' (2006) scenario may also help to make the turn out of an impasse.

Fourier spectra

For Blazhko stars, classical Fourier techniques result in a frequency spectrum containing a multitude of frequency peaks and side peaks (see Figure 1). The main frequency and its harmonics are easily identifiable. The side peaks, generally equally-spaced triplet structures centered around the main frequency and its harmonics, are also clearly detected. Several authors have attributed the side peaks near the main frequency f_0 to the occurrence of at

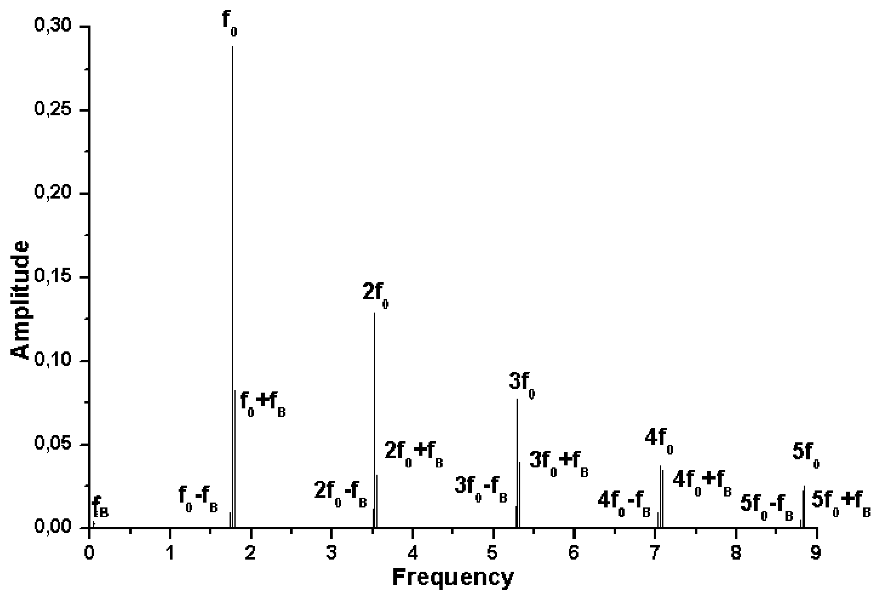

Figure 1: Frequency spectrum resulting from the latest RR Lyr photometric campaign.

least one nonradial mode in the star. No radial mode would have a frequency so close to f_0. The often observed unequal amplitudes in the triplet structures cannot be described in the extent observed by the models.

It was recently shown by Hurta et al. (2008) that the variations of the star RV UMa can be described by a quintuplet solution rather than a triplet. Also Kolenberg et al. (2008a) find evidence for quintuplet frequencies in data of the southern Blazhko star SS For. With the increasing quality of data sets on Blazhko stars and the advent of high-quality quasi-uninterrupted satellite data, we may expect to detect many more quintuplet (generally: multiplet) structures in data of Blazhko stars in the near future.

Changing Blazhko periods

Changing Blazhko periods represent an additional challenge to the currently proposed hypotheses for the Blazhko effect. Several Blazhko stars are known to have shown changes in their Blazhko period (e.g. XZ Cyg - see LaCluyzé et al. 2004; RR Lyr - see Kolenberg et al. 2006). RR Lyr is one of the best studied Blazhko stars and over the past decades gradually decreasing values of its modulation period have been reported: from 40.8 days (Fringant 1961; Szeidl 1988), over 39-40 days (Belserene 1999; Smith et al. 2003) to values below 39 days (Kolenberg et al. 2006; Kolenberg et al. 2008b).

A way to analyze the changing periods in Blazhko stars

The Blazhko frequency itself can be observed in time series data when the quality and time coverage of the set is sufficient. Jurcsik et al. (2006) pointed out its discrepant behaviour. If observed (with small amplitude) in the frequency spectrum of a Blazhko star, the colour behaviour of the Blazhko frequency differs from that of the main frequency, its harmonics and the adjacent sidepeaks. The side lobe frequencies in the triplets seem to share the same colour behaviour as the main frequency and its harmonic.

This observation supports the hypothesis of a single mechanism, acting on the time scale of the Blazhko frequency, causing the Blazhko effect. From our observations it seems that this time scale may also vary.

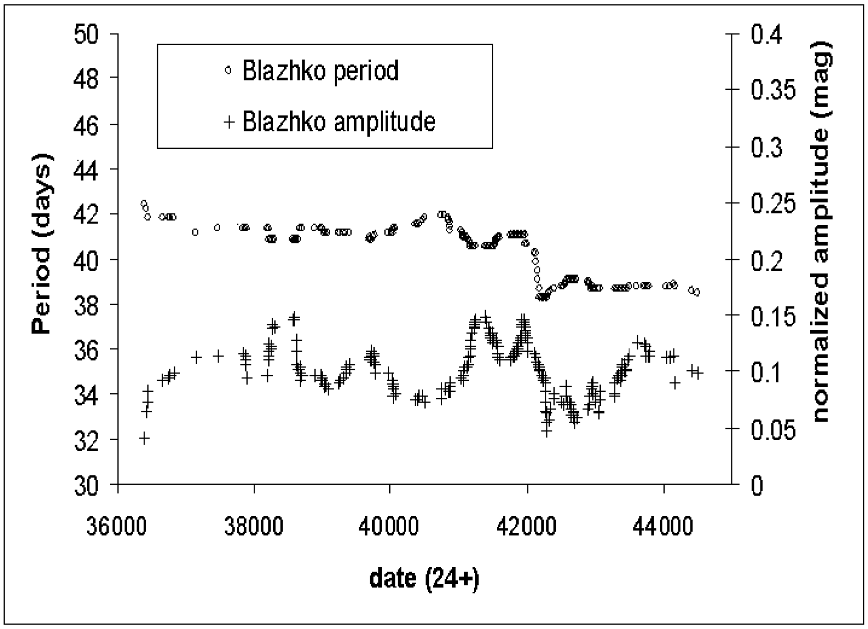

Figure 2: Blazhko period changes in RR Lyr between 1958 and 1980 determined with the VSAA.

The Variable Sine Algorithmic Analysis (Tsantillas & Rovithis-Livaniou 2008) provides a tool that can easily be applied to times and amplitudes of maximum light of the Blazhko effect.

Szeidl et al. (1997) compiled half a century of photometric data gathered at Konkoly observatory between 1943 and 1993. For a uniform subset of the data, gathered between 1958 and 1980, we selected the maxima in order to investigate the changes in the strength (amplitude) and duration (period) of the Blazhko cycle. The results of the VSAA (Figure 2) show a long-term decrease of the Blazhko period with possibly small periods of increase. Started from a value close to 41 days, the Blazhko period has decreased to below 39 days over the past few decades. From our analysis the Blazhko amplitude seems to oscillate around a constant value.

We also applied the VSAA to two recent data sets of RR Lyr, gathered in 2003-2004 and in 2006-2007. The frequency spectrum obtained through Fourier analysis for the latter one is shown in Figure 1. Note that in our Fourier analysis the Blazhko frequency f_B obtained a fixed value. When applying the VSAA to the set of obtained maxima of our data set, we find evidence of a changing Blazhko period, even during our observing run (see Figure 4, Tsantillas & Rovithis-Livaniou 2008).

The results obtained with the VSAA also confirm our observations of a shortening Blazhko period for RR Lyrae obtained using Fourier techniques (see also poster by Kolenberg et al. 2008b).

Discussion

As a first application, we applied the VSAA in an elementary way to trace the *changes of the Blazhko period*.

In a future application, we will extend the technique to be applied to non-sinusoidal light variations such as observed in RR Lyrae stars. This will allow us to trace the *frequency and amplitude variations of the main pulsation mode*. In such an application, both the main frequency and the amplitudes of both this frequency and its harmonics are traced in their variations over the Blazhko cycle. The difference with the analysis of Fourier parameters as presented by Jurcsik et al. (2005) and Kolenberg et al. (2006) is that in the VSAA we allow the period itself to change over the Blazhko cycle. This is equivalent to changes in the phase when keeping the period constant.

If structural changes happen in the star over the Blazhko cycle, it is possible that the mean temperature, luminosity and radius of the star show a variation over the Blazhko cycle. Hence, allowing a variable pulsation period over the Blazhko cycle in the analysis may offer an interesting alternative to the classical Fourier technique when analyzing Blazhko time series data.

What physical mechanism causes the change in Blazhko period and amplitude, and the variation in pulsation period and amplitude, i.e., what causes the Blazhko effect altogether, is a question that will hopefully be answered in the near future.

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DISCUSSION

Kovács: I agree with you that the major problem in the current models of the Blazhko effect is of finding an explanation for the widely observed asymmetric modulation side lobe components. In comparison, the model preference based on triplet vs. quintuplet interpretation is of secondary importance.

Kolenberg: Indeed, none of the presently proposed models manages to explain the side peak asymmetry in the degree it is observed. Both in the resonance model and in the magnetic model there are attempts to reproduce the asymmetry of the side peaks. But in reality we often see even more pronounced asymmetry.

Kovács: I feel a major problem (or misunderstanding) with Stothers' idea for explaining the Blazhko effect. The major ingredient of his idea is based on the asymptotic period change (linear vs. nonlinear) in nonlinear hydrodynamic simulations. Currently available results (see the works of Buchler, Szabo & Kollath) show that this change is always positive, leading to (slight) period increase. In addition, these changes occur on very large time scales (thousand pulsational cycles, depending on model initialization), whereas there are Blazhko stars with modulation periods under 10 days.

Kolenberg: Thanks for this valuable comment. As you say, the Stothers' scenario also does not fully explain the observations. In general, I encourage the exploration of alternative paths (including those that do not require the existence of nonradial modes) in trying to solve the Blazhko puzzle.